DOCUMENT RESUME

ED 379 313 TM 022 675

AUTHOR	Cennamo, Katherine S.
TITLE	Techniques of Assessing Mental Effort.
SPONS AGENCY	Purdue Univ., West Lafayette, IN. School of Education.
PUB DATE	[92]
NOTE	21p.
PUB TYPE	Information Analyses (070) -- Reports - Evaluative/Feasibility (142)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Academic Achievement; *Cognitive Processes; *Educational Assessment; Educational Technology; Literature Reviews; *Measurement Techniques; Opinions; Physiology; Research Reports; *Test Use; Videodisks; Videotape Recordings
IDENTIFIERS	Amount of Invested Mental Effort; *Mental Effort

ABSTRACT

The search for techniques to increase the effort that learners invest in video-based instruction has been hindered by the limitations of the instruments used to assess the construct of mental effort. Several researchers have noted the confusion of terms in the field that refer to the cognitive resources devoted to processing the stimulus. In this paper, relevant literature in communications, education, psychology, and human factors engineering are reviewed to identify techniques that have been used successfully to assess mental effort. Methods of assessing the construct of mental effort fall into three main categories: opinion measures, dual tasks techniques, and physiological measures. The most promising methods are described, and studies which have applied these methods are summarized. The relationship between assessments of mental effort and achievement scores are discussed. A table charts the sensitivity of measures of the three types. (Contains 44 references.) (Author/SLD)

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Techniques of Assessing Mental Effort

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Katherine S. Cennamo

Purdue University
West Lafayette, Indiana

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The preparation of this document was partially supported through a Faculty Incentive Grant and Undergraduate Research Trainee Grant awarded through the College of Education, Purdue University, West Lafayette, Indiana.

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Techniques of Assessing Mental Effort

Although the fact that learners invest less mental effort in television instruction than in print-based instruction has been documented (Salomon, 1983; Salomon, 1984; Salomon & Leigh, 1984), the search for techniques to increase the effort that learners invest in video-based instruction has been hindered by the limitations of the instruments used to assess the construct of mental effort.

Early work (Salomon, 1983; Salomon, 1984; Salomon & Leigh, 1984) that investigated the amount of effort learners invested in print and video-based instruction used self-report questionnaires to document the learners' effort expenditures. Recently, however, researchers (Beentjes, 1989; Cennamo, Savenye, & Smith, 1991) have identified a need for more precise methods of assessing mental effort.

A recent study (Cennamo, et. al., 1991) incorporated a questioning technique that has been shown to increase the effort invested in print-based materials (Britton, Piha, Davis, & Wehausen E. 1978; Burton, Niles, & Lalik,1986) into video-based materials to determine whether the technique effectively increased the effort invested in video and print in a similar manner. Although there were significant differences among the groups on a test of cued recall, there were no significant differences among the groups in the amount of mental effort reported on a self-report questionnaire. It is the opinion of the researchers and several anonymous reviewers of the manuscript that the findings of the study were severely limited by the instrument used to assess mental effort. Mental effort was assessed by means of a questionnaire that was developed by combining the questions used by Salomon in two studies (1983; 1984). Although Salomon reported an acceptable level of reliability in his studies, in this study, the Cronbach's alpha of .55 was unacceptably low.

Beentjes (1989) attempted to replicate Salomon's findings using the instruments developed by Salomon. Although he reports an acceptable degree of internal consistency for the instrument used in his study, he states "... the validity of the AIME (Amount of Invested Mental Effort) instrument is a point of concern. Although self-reports about an intentional process like investing mental effort are possible in theory, validation studies in which mental effort is assessed by multiple methods are called for. " (p. 56).

Several researchers (Britton, Muth, & Glynn, 1986) have noted that the terms mental effort, attention, concentration, use of cognitive capacity, and mental workload all refer to similar concepts and refer to an increase in the cognitive resources devoted to processing the stimulus. In this paper, the relevant literature in communications, education, psychology, and human factors engineering will be reviewed to identify techniques that have been used

successfully to assess mental effort. The most promising methods will be described, studies which have applied these methods will be summarized, and the relationship between assessments of mental effort and achievement scores will be discussed.

Potential Techniques and Methods

Methods of assessing the construct of mental effort fall into three main categories: opinion measures, dual tasks techniques, and physiological measures. These categories parallel the areas of introspection, information processing, and neural processing identified by Posner (1982).

Opinion measures

Opinion measures encompass the variety of self-report measures used to assess mental effort. Opinion measures assume that the investment of effort is a voluntary process which is under the control of the individual, and as such, is available for introspection.

Inventory of Learning Processes (ILP) scale The Inventory of Learning Processes (ILP) scale (Schmeck, R. R., Ribich, F. & Ramanaiah, N.,1977) consists of 121 true and false items designed to measure individual differences in learning processes. The test is divided into four subscales and cores on the Deep-processing and Elaboration subscales have been shown to have a significant correlation with scores on achievement measures (Gadzella, Ginter, & Williamson, 1986; Gadzella, Ginter, & Williamson, 1987). The Deep-processing scale consists of 18 items which assess the extent to which the learners evaluate, analyze, and organize information. The Elaborative Processing scale consists of 14 items which assess how students translate and visualize information.

Amount of Invested Mental Effort (AIME) questionnaire The AIME questionnaire was developed by Salomon (1983) to assess learners' perceptions of the amount of effort they invest in processing print and video-based instruction. Learners are asked to respond on a four point Likert scale of effort to a set of questions concerning the extent to which they concentrated during the lesson, how hard the lesson made them think, how hard the lesson was to understand, and similar questions. In a variety of studies (Beentjes, 1989, Cennamo, et. al, 1991; Salomon, 1983; Salomon, 1984; Salomon & Leigh, 1984; Salomon, Globerson, & Guterman, 1989), as few as three and as many as eighteen questions have been included in the AIME questionnaire.

Other opinion scales In addition to the scales used to assess the effort invested in educational tasks, several similar scales have been used to assess the mental workload involved in operating a flight simulator. The Cooper-Harper aircraft handling rating scale, Workload Compensation Interference/ Technical Effectiveness scale, and Multi-Descriptor scale (which required participants to rate the attentional demand, error level, difficulty, task complexity,

mental workload and stress level of the task) have been used successfully in this performance tasks (Casali & Wierwille, 1983; Wierwille & Connor, 1983; Wierwille, Rahimi, & Casali, 1985).

Dual task techniques

Dual task techniques encompass a range of methods which assign the learner a primary task such as reading a passage, working a problem, or viewing a videotape, and also assign the learner a secondary task such as responding to a tone, finger tapping, or estimating a time internal. Dual task techniques assume that there is a limit to the learner's cognitive capacity, and when a great deal of cognitive capacity is consumed by the primary task, there will be less capacity left to devote to the secondary task. Dual task techniques assume that the differences between performance on a baseline measurement of the secondary task and performance under experimental conditions is an indication of the amount of effort expended on the primary task.

Finger tapping In the finger tapping method (Kee & Davis, 1988; Kee & Davis, 1990; Casali & Wierwille, 1983; Wierwille, Rahimi, & Casali, 1985), learners are directed to tap a key as quickly as possible. An electronic counter records the frequency of the finger taps. A baseline measurement is recorded prior to the introduction of the primary task. The decrease in performance on the finger tapping task is used as an indication of the effort expended in the primary task.

Secondary task technique In the secondary task technique, (c. f. Britton, Muth & Glynn, 1986; Gilbert & Scheuder, 1988; Meadowcroft & Reeves, 1985) learners are directed to press a key as quickly as possible following a visual or auditory signal. A baseline measurement is recorded prior to the introduction of the primary task. The increase in the time required to respond to the visual or auditory signal when attending to the primary task is assumed to be an indication of the effort expended in the primary task.

Other dual task methods Other techniques that have been used in assessing mental workload when operating a flight simulator are digit shadowing, memory scanning, time estimation, and mental arithmetic tasks. In the digit shadowing technique, digits were presented on a screen and participants were required to read the digits aloud. A participant's score consisted of the number of digits presented but not read aloud (Wierwille & Connor, 1983). In the memory scanning task, participants heard a voice recording of digits and they were to push a lever to indicated whether the digits were the same or different digits than those presented on a screen . The mean time required to correctly respond to the stimulus was used as an indication of mental workload (Wierwille & Connor, 1983). The time estimation task required the participant to press a lever ten seconds after receiving a cue to begin estimating the interval. The standard deviation of the participant's time interval estimates was used as an indication of

the effort invested in the primary task (Casali & Wierwille, 1983; Wierwille & Connor, 1983; Wierwille, Rahimi, & Casali, 1985). In the mental arithmetic task, participants were presented with verbal math problems requiring single digit responses. Participants responded verbally and their scores consisted of the percentage of incorrect responses to the problems presented (Wierwille & Connor, 1983).

Physiological measures

These techniques assume that there is a physiological response to increases in effort expenditure. The difference between a learners' baseline measurement of the physiological process and a measurement taken while the learner is performing some task is assumed to be reflective of the amount of effort the learner is investing in the task.

Heart rate In this technique, the pulse rate of the learner is monitored to determine if there is an increase in heart rate while attending to the learning task. It is assumed that increased heart rate is a natural physiological response to tasks that require information processing (Thorson & Lang, 1992).

Electroencephalogram (EEG) measures The EGG records the electrical activity of the brain using electrodes attached to the scalp of the learner. It is assumed that the amount of alpha frequency present in the EEG varies inversely with the amount of mental activity (Reeves, Thorson, & Schleuder, 1986).

Other physiological techniques Other measures that have been used in performance tasks include eye fixations, pupil diameter, number of eye blinks per minute, respiration rate in breaths-per- minute, and voice patterns as analyzed by a computerized psychological stress evaluator (Casali & Wierwille, 1983; Wierwille & Connor, 1983; Wierwille, Rahimi, & Casali, 1985; Reeves, Thorson, Schleuder, 1985).

Applications

A series of studies in human factors engineering (Casali & Wierwille, 1983; Wierwille & Connor, 1983; Wierwille, Rahimi, & Casali, 1985) have attempted to determine the sensitivity of 15 different assessment measures for detecting variations in the workload placed upon an operator of a flight simulator (see Table 1). In these studies, the operators were presented with a series of tasks that ranged from easy to difficult to determine the effects of these manipulations on their scores on a variety of measures. The possible interference effects of the assessment measure on performance of the primary task was also investigated. The tasks performed by the operator were divided into perceptual tasks, psychomotor tasks, communication tasks, and mediational (cognitive problem solving) tasks. The researchers found that the techniques which were most sensitive to manipulations in the operator workload varied depending on the type of task performed by the operator. For example, eye blinks and eye

fixation measures were sensitive to increases in the difficulty of a cognitive task, but were not sensitive to increases in the difficulty of a communication task. Although one of the opinion scales (Modified Cooper-Harper) and the time estimation task were sensitive to increases in operator demands across all four types of tasks, the time estimation task resulted in an increase in the error rate of subjects who were performing the cognitive task.

Insert Table 1 about here

These results suggest that educational researchers who desire to assess the mental effort invested in learning tasks may need to take into consideration the type task required of the learner. The following section will describe a several studies which have investigated the amount of effort invested in a variety of perceptual and cognitive tasks. Although this review of the literature failed to locate instances where mental effort was assessed during the performance of communication or psychomotor tasks, the application of mental effort assessment techniques to tasks of this nature should not be neglected in future research.

Perceptual tasks

The following studies assessed the mental effort expended in various perceptual tasks.

Dual Task techniques

Secondary task technique.

- The secondary task technique has been used to examine learners' responses to the perceptual demands of television processing. Reeves and Thorson (1986) found that cues that occurred during a complex moment in a television commercial elicited longer reaction times than cues that occurred during less complex moments. Complexity involved both auditory elements such as the sentence syntax and visual elements such as pans, zooms, and movement within the scene. However, messages that contained a larger number of complex elements produced faster reaction times than messages that were less complex. Reeves and Thorson proposed that for simple messages, it may take more effort to construct meaning from the overall message than needed for more complex messages. The message in these experiments consisted of a series of 30-second commercials.
- When learners were presented with a videotaped message that was presented over the audio channel, the visual channel, or both channels, their reaction times were slower when attending to both channels than when attending to either channel by itself. Audio-only required more effort to process than video-only, but this effect may have been due to the competition for auditory resources caused by the auditory probe (Reeves, Thorson, & Schleuder, 1985).

- The effects of competition for resources was evident in a study that investigated the effects of visual and auditory complexity using audio-only, video-only, or audio-video conditions. The researchers (Thorson, Reeves & Schleuder, 1985) found that the type of secondary task probe affected the pattern of learners' reaction times to a secondary task. When learners were presented with messages that were either visually simple, visually complex, auditorially simple or auditorilly complex under video-only, audio-only, or audio-video conditions, the channel that exhibited sensitivity to variations in complexity, as measured by slower reaction times to the secondary task, depended on the channel through which the secondary task probe was presented. When learners were asked to respond to a auditory tone, there were no significant main effects for auditory complexity and video simple messages produced longer reaction times than video complex messages. On the other hand, when learners were asked to respond to a light flash, there were no significant main effects for video complexity, but audio simple messages produced longer reaction times than audio complex messages.

Reaction time measure

- Gilbert and Schleuder (1988) had students look at black and white or color pictures and determine whether the caption matched the picture. The amount of time the students required to determine whether the caption and picture matched was assumed to be a reflection of the effort expended in the task. They found that students used less effort (faster response times) to correctly identify a match when viewing color photographs than with the black and white images.

Physiological measures

Electroencephalogram (EEG) measure

- When Reeves and Thorson (1986) used a measure of EEG responses to determine learners' responses to the visual and auditory complexity of a series of 30-second television commercials, they found rapid declines in alpha (indicating increased attention) during complex moments in the commercial. These rapid declines in alpha could be attributed to the orienting response that occurs when an individual is presented with new stimuli.

Cognitive tasks

The following studies assessed the mental effort expended in performing various cognitive tasks.

Opinion measures

Self-reports

- Bordeauz and Lange (1991) asked children in grades two, four, and six about the effort they invested in nine types of television programs (cartoons, children's programs, family shows, situation comedies, news or documentary, entertainment shows, adventure or action programs, sports, and soap operas). These investigations examined learners perceptions of their overall effort investment in a particular type of program, and as such, are reflective of learners preconceptions of the effort required to process particular program types. However, these investigations differ from those that present the learners with a specific television program and ask the learners to rate the amount of effort invested in that specific program.
- Salomon (1983; 1984; Salomon & Leigh, 1984) used self-report questionnaires to assess the amount of mental effort that learners perceived they invested in processing television and print. In these studies, sixth-grade students were presented with a story to read or to view on videotape. They consistently found that the students reported investing less effort in processing the video-taped version than in processing the text-based version of the story. In general, they reported that students who read the print-based version performed better on a test of recall and inference items than the students who viewed the videotaped version. In addition, students who were instructed to learn from the story reported investing more effort in processing the story than those who were instructed to read or view the story for fun.
- Cennamo, Savenye and Smith (1991) used a similar questionnaire to assess learners perceptions of the amount of effort they invested in processing interactive video and video-based instruction. Learners either viewed a videotape of a science lesson, viewed a videotape of the same lesson with practice questions and feedback, or completed a videodisc version of the lesson that required the learners to actively respond to the embedded questions before they would receive feedback on their response. The researchers found no significant difference among the groups in their ratings of invested effort.
- Chu (1987) used a self-report questionnaire modeled after Salomon's in her study that used computer-assisted instruction to examine the effects of student generated underlining, program generated underlining, and free choice of the underlining option on learners' perceived mental effort and achievement. There were no significant differences in performance among the three groups on a recall posttest, and, unfortunately, she did not compare the mental effort ratings among groups. However, she did report a weak but significant correlation between learners perceptions of the task difficulty and their perceived mental effort ratings.

Dual task techniques

Finger tapping

- Kee and Davis had students tap while they attempted to learn various noun pairs that were presented aurally. Students were asked to use a variety of strategies as they memorized the noun pairs: repeating silently or orally (1988), generate a sentence with the noun pairs orally (1988) or silently (1988, 1990), learning a sentence containing the noun pair (1990) or however they wished (1990). Although the strategies used for memorization did not affect finger tapping speed significantly in the majority of cases, finger tapping speed decreased significantly when the learners were memorizing noun pairs with no logical connection using the strategy that required them to generate a sentence containing both nouns.

Secondary task technique

The secondary task technique has been used extensively in a variety of research studies that examined students' performance of cognitive tasks.

- Meadowcroft and Reeves ()used the secondary task technique to determine the amount of effort that children invested in processing cartoons. The cartoons were presented in a jumbled or normal form. The researchers found that the students allocated more attention to scenes that were central to the story content than to extraneous scenes. Children that appeared to have well developed schema exerted less effort in processing the content of the programs than those who had low levels of schema development.
- Grimes (1990) used a secondary task technique to determine the effects of the degree of match between the audio and video portions of a television program. He presented the learners with a program that either had a high degree of correspondence between what was talked about and seen on the screen, a thematic match between the two channels (medium correspondence) or no correspondence between the two channels. The learners were told to learn all that they could for a test following the program. Grimes presented the secondary task over either the visual or auditory channels. He found no significant differences among reaction times to the auditory probe among the three correspondence conditions; however, when a visual probe was used, the high correspondence condition resulted in significantly slower reaction times than the other conditions.
- Cameron, Schleuder, and Thorson (1991) had learners watch a series of newscasts that included commercial breaks. Half of the commercials breaks were preceded by teasers and half were not. The learners were told that they would be tested over what they had seen. A secondary task technique was used to determine the effect of news teasers on the learners attention to the commercials. The reaction times to tones which occurred during

commercials preceded by teasers were significantly slower than the reaction times to tones which occurred during commercials with no teasers. With teasers, the middle commercial elicited the longest reaction times, but when there were no teasers, the first and last commercial elicited longer reaction times.

- Shapiro (1985) had participants respond to a visual secondary task (a light flash) while listening to an audio-taped science passage. He examined the effects of the presence of analogies and the effects of visualization training on learners reaction times and achievement scores. His results suggest that learners who received the lessons with analogies and learners who were instructed to visualize the content may have used more effort during the processing of the lesson; however, there were no significant differences on recall scores.
- Reed, Burton and Kelly (1985) used a secondary task technique to determine learners cognitive engagement during a writing assignment. English students enrolled in an honors class, an average class, and a remedial class were asked to write a narrative, persuasive, or descriptive essay. They found that the writers ability differentially affected their cognitive engagement across modes of writing. For example, honors writers had the longest reaction times to the secondary probe when writing persuasive essays, but shorter reaction times when writing descriptive essays. Average students, on the other hand, exhibited their longest reaction times when writing descriptive essays.
- Britton and other researchers have used the secondary task techniques extensively in their investigation of the processing of text-based materials. They have presented learners with a variety of printed messages to determine the effects of prior knowledge of the content (Britton & Tesser, 1982), meaningfulness of the passage (Britton, Holdredge, Curry & Westbrook, 1979), expectations of delayed and immediate tests (Britton, 1980), narrative and expository text (Britton, Graesser, Glynn, Hamilton, & Penland, 1983), embedded questions(Britton, Piha, Davis, & Wehausen, 1978; Burton, Niles, & Lalik, 1986), interest (Shirey & Reynolds, 1988), text syntax (Britton, Glynn, Mayer, & Penland, 1982), objectives (Britton, Glynn, Muth, & Penland, 1985).

Letter identification task

- White (1986) used a letter identification task to measure the workload on the sensory register. Subjects viewed videotaped PSAs (public service announcements) of varying complexity levels and were asked to simultaneously pull a lever when they identified letters which also appeared on the screen. As the complexity of the television image increased, performance on the letter identification task decreased. The author concluded that the letter identification task may have interfered with learning.

Physiological measures

Heart rate

- Although learners' heart rates were monitored to determine if there were differences in the effort expended in processing videotaped lectures covering familiar and unfamiliar content and including complex and simple video graphics, the heart rate patterns did not show any significant differences in the effort expended in processing the four types of lectures (Thorson & Lang, 1992)

Correlation of Mental Effort Measurements and Achievement

Opinion measures

Self-report questionnaires

Salomon found a significant correlation between learners self-reports of invested mental effort and their scores on a test of inference items. In general, he found that learners who received a print-based version of a lesson reported investing more mental effort in processing the lesson than those students who received a video-based version of the lesson. in addition, the students who received the print-based version achieved higher scores on a test of inference items than those who received the video-based version. Cennamo, Savenye and Smith (1991) also reported a weak, but significant correlation between learners self-reports of invested mental effort and their scores on a test of recall and inference items. They found that learners' test scores tended to increase as their perceived mental effort ratings increased.

Inventory of Learning Processes

This instrument is administered prior to a learning task and assesses learners tendencies to elaborate and process deeply. Learners who scored high on the deep processing scale had higher scores on a test of free and cued recall following a cooperative learning activity where they had to read and study a passage describing a piece of technical equipment, stopping periodically to summarize the information to one another, than learners who with low scores on the deep processing subscale (Skaggs, et. al.,). Other researchers (Gadzella, et. al., 1986) found that there was a significant correlation between students overall grade point average and there scores on deep processing subscale. They also found that students who completed a computer-assisted instructional lesson designed to teach study skills showed a significant correlation between scores on the deep processing subscale and their scores on a test assessing their knowledge of some study skills (Gadzella, et. al. 1987).

Dual task techniques

Finger tapping

Kee and Davis found significant differences for recall in several instances where there were no significant differences in speed of finger tapping. Students who were asked to generate a sentence recalled significantly more noun pairs than students who rehearsed the pairs (1988; 1990) and that logical pairs were more easily recalled than illogical pairs (1990); however, finger tapping speed was not significantly altered except for the instance where learners were required to generate a sentence containing a pair of nouns that had no logical connection.

Secondary task technique

There are four possible patterns of scores on achievement measures and a reaction times to a secondary task: a) longer reaction times may correspond to higher recall scores, b) longer reaction times may correspond to lower recall scores, c) there may be no significant difference in reaction times among the groups, yet there may be significant differences on recall measures, or d) there may be significant differences on reaction times and no significant differences in recall scores.

Longer reaction times- Higher recall scores.

- Grimes (1990) found the same pattern of scores on a visual recognition test and reaction times to a visual probe. He found that reaction times were slowest for the high correspondence condition, and fastest for the medium correspondence condition. Scores on the visual recognition test followed the same pattern, with learners who viewed the program with high correspondence scoring highest, followed by those who viewed the program with no correspondence, and finally, those who viewed the program with only a thematic match between the visual and the audio portion of the program.
- In a task that required learners to write a variety of essays, Reed, Burton and Kelly (1985) found that reaction times to a secondary task were positively related to scores of writing quality.
- Britton, Muth and Glynn presented learners with a text passage and found that when there were no time pressures, students spent more time in the reading of important information than in reading less important information; however, when the learners were restricted in the time spent on reading the text passage, more effort was spent on processing important sentences than unimportant ones. Important information was also recalled more often than unimportant information.
- Briton, Westbrook and Holdredge (1978) found that learners exerted more effort in reading easy passages than in reading difficult passages and they also recalled significantly more information from the easy passages.

- Britton, Glynn, Muth, and Penland found that learners who were aware of the specific objectives of a passage exerted more effort in processing the passage and also recalled more information from the passage than learners who were presented with a general objective or no objectives.

Longer reaction times- Lower recall scores

- Cameron, Schleuder, and Thorson (1991) found an interesting relationship between learners' scores on a multiple choice visual and verbal recognition test and their reaction times to a secondary task. In an experiment that examined the effects of news teasers on learners attention to commercials during a newscast, they found that verbal memory was higher for the first and last commercials during a commercial break that had been preceded by a news teaser, but that reaction times for the first and last commercial were shorter (so presumably less effort was expended) than for the middle commercial.
- Shirey and Reynolds (1988) presented learners with a series of sentences on a computer screen. They found that students recalled sentences rated as interesting at a higher rate than those rated less interesting; however, less effort was allocated to the interesting sentences than the uninteresting ones. More effort was allocated to reading uninteresting sentences.
- Britton, Glynn, Mere, and Penland found that learners who read a technical text that was written using common words answered more questions correctly than learners who read the technical text that used rare words. In addition, those students who read the technical text written with simple syntax answered more multiple choice questions correctly than those who read a version written with complex syntax. The reaction time measures indicate that learners allocated more effort to reading the text with complex syntax than to reading the text with simple syntax. The differences in reaction time between those who read the text with common and rare words were not significant.
- Lang (1991) found that learners exerted more effort in processing video segments that included video cuts that were represented changes in content than they did in processing cuts that were related in content to the preceding information. However, the learners recalled more of the information surrounding related cuts than surrounding unrelated cuts.

Difference in reaction times- No difference in recall scores

- Reeves, Thorson, and Schleuder (1985) found no significant differences in learners performance among the audio-only, video-only or audio-video conditions. However, there were significant differences among the three groups in reaction times to a tone;

reaction times were significantly delayed for those who attended to the audio-video presentation.

- Often there are significant effects on performance measures with no corresponding effects on reaction times to a secondary task; however, in a study that examined the effects of analogies and visualization training on learning a science passage, Shapiro (1985) found significant effects on reaction times with no corresponding effects on an achievement measure.
- Another experiment (Britton, Glynn, Mere, & Penland, 1982) found that learners who read a text that included text "signals" (such as therefore, consequently, and likewise) allocated less effort to reading the text than learners who read a version that did not include signals. However, there were no significant differences among the groups on a measure of free recall.
- Britton (1980) found that learners who expected a delayed test used more effort in reading the passage than those who expected an immediate test; however, there were no significant differences between the groups in the amount of information recalled.
- Although Britton, Holdredge, Curry and Westbrook (1979) found that learners exerted more effort in reading passages which contained a title that related the sentences to each other than in reading the same passage that was meaningless without the title, there was no significant difference between the two conditions on recall scores.

No difference in reaction times- Difference in recall scores

- Readers recalled more information from a paragraph that appeared in a context that emphasized the importance of the content than they did from the same paragraph in a context that minimized its importance; however, there was no significant difference in the learners' reaction times between the two conditions (Britton, Mere, Simpson, Holdredge, & Curry, 1979).

Physiological measures

Electroencephalogram (EEG) measure

Reeves and Thorson (1986) found that lower mean levels of alpha in response to a 30-second television commercial correlated with increased memory of the content of the message.

Heart rate

Thorson and Lang (1992) examined the effects of video graphics inserted into videotaped lectures on content with which the learners were either familiar or unfamiliar. Although they found significant differences among the treatment conditions on a measure of recall, there were no significant differences among treatments on the heart rate patterns. Memory for information

following the video graphic in the familiar lectures was improved, but memory for information following the graphic in the unfamiliar lectures was decreased.

Conclusions

Winn (1986) indicated that an investigation of ways that designers can alter the perceptions of learners to increase the amount of mental effort invested in processing the lesson may be an especially promising area for further research. However, the search for techniques to increase the mental effort invested in processing a video-based lesson has been hindered by the methodology available to assess the construct of mental effort. There is a need for educational researchers to determine the sensitivity of techniques of assessing mental effort to increases in the processing requirements of a lesson; this literature review is an initial step in that direction.

Table 1

Effectiveness of techniques used to assess mental workload

Assessment Measure	Perceptual	Psychomotor	Communication	Mediational (cognitive)
OPINION MEASURES				
Modified Cooper Harper scale (Cooper Harper scale in psychomotor)	X	- X	X	X
Multi-descriptor scale	X	-	X	O
Workload compensation interference/ technical effectiveness scale	X	X	-	X
SECONDARY TASKS				
Time estimation standard deviation	X	X	X	X
Tapping regularity	X	-	O	O
Digit shadowing	-	O	-	-
Memory scanning	-	O	-	-
Mental arithmetic	-	0	-	-
PHYSIOLOGICAL				
Respiration rate	X	0	O	O
Heart rate mean	O	X	O	O
Heart rate variability (SD)	0	O	0	O
Pupil diameter	O	0	X	O
Eye blinks	O	-	O	X
Eye fixations	-	-	O	X
Voice pattern scores	-	O	-	-

KEY

0 not sensitive to differences in workload
X sensitive to differences in workload
- not assessed

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